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THE SANITARY LANDFILL METHOD OF REFUSE DISPOSAL IN NORTHERN STATES

Leo Weaver, et al

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the SANITARY LANDFILL

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THE SANITARY LANDFILL

METHOD OF REFUSE DISPOSAL

IN NORTHERN STATES

by

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FEDERAL SECURITY AGENCY • Public Health Service

I

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FOREWORD

This report covers the origin and development of a joint experimental operation of the North Dakota State Health Department, the City of Mandan, North Dakota, and the Public Health Service. It presents data and observations of interest to health and public-works authorities in all States and municipalities, particularly in those areas which experience severe winter conditions, and which still rely on the open dump for the disposal of solid wastes.

The safe, sanitary, and economical disposal of refuse has long posed a serious problem for such communities—particularly for those with populations of 10,000 or less. In areas where the climate is amenable, as in the South, the sanitary landfill has been utilized with considerable success; but its use in colder climates has been considered impracticable, because of problems created by freezing weather, such as the depth of frost penetration of the ground. Many Northern towns and villages, therefore, have tended to depend almost exclusively on the open dump, which does not get rid of refuse, but makes of it a breeding place for flies and other disease-bearing insects, a harborage for rats and other vermin, a hazard for children who are drawn to it as a place to play, and in other respects, a menace to public health and safety.

These reasons prompted the Public Health Service to respond to the request of the North Dakota State Health Department for a joint study, and actual test, of the sanitary landfill under extreme winter conditions. We feel that the test has been successful, and that the report of Messrs. Weaver and Keagy will be of considerable interest and assistance to many communities whose situation and circumstances approach those of Mandan.

C. H. Atkins, *Chief*
Division of Sanitation
Public Health Service

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INTRODUCTION

The North Dakota Water and Sewage Works Conference, at its 1947 meeting, appointed a committee to study the State's refuse collection and disposal problem. The results, published in the *Official Bulletin*, North Dakota Water and Sewage Works Conference of September 1948, disclosed that of 135 municipalities reporting on disposal methods, 129 used the open dump; three used incinerators (which because of age and resulting high operating costs, have since been abandoned); and three relied on the open-face-dump form of landfill.

Seeking a solution to the problem, the State Health Department faced a number of handicaps: (1) The State is sparsely populated. Fargo, the largest city, has only 38,256 inhabitants (1950 census). (2) The extreme winter weather made the utility of the sanitary landfill questionable. (3) Since communities in the State must observe State laws limiting taxation, few, if any, were able to obtain funds for incinerator construction and operation.

Fig. 1. Directional Sign to Project

Most sanitary engineers who have reported on the subject agree that, where suitable land is available, the sanitary landfill is probably the most economical sanitary method of refuse disposal. The Public Health Service, Federal Security Agency, accepted the State Health Department's invitation to cooperate in a study of landfill techniques in winter conditions in North Dakota, since they are typical of those in other northern States. Mandan was selected, in March 1949, as the site of an experimental project.

The City of Mandan has a population of 7,298 (1950 census). The City collects refuse from its residential areas on a fee basis. Business establishments either haul their own refuse, or contract with private haulers.

The Public Health Service provided the services of an engineer and made available the necessary heavy equipment for a 1-year period. Also, a front-end-loading tractor was loaned to the City by a manufacturer for the purpose of this experiment, and was utilized during the first year's operations. The City provided the site, hired an equipment operator, and assumed other costs. The State provided traveling expenses and office space. It was agreed that the City should continue the operation if the project proved successful.

The experiment met with marked success during the first year of operation, and the City of Mandan assumed control of operations on July 1, 1950. Since a 2-year period of observation was considered necessary for the various technical studies in progress, the Public Health Service provided the services of a sanitary engineer for a second year. While some questions still remain, we believe that important information has been added to our knowledge of this method of disposal during this 2-year period.

It is felt that the accomplishment of this experiment was largely due to the cooperation of all who were concerned with it. Valuable contributions were made by the Bureau of Reclamation, the Fish and Wildlife Service, the State and City Health Departments, as well as the Mandan City Council and City Engineer.

It is sincerely hoped that this report will do justice to the efforts of all who must share the credit for a successful and important experiment.

The First Site

Two sites were favored for the landfill out of several possible: (1) a 20-acre tract, held under option, 1.3 miles south of the main street, and (2) the City's open-face-dump area, located close to the center of town on low, submarginal land, which filling would make usable. The 20-acre tract was selected by the City Commissioners because of the experimental nature of the project. The Public Health Service approved this site, because it was well-suited for the trench method of landfill operation, and thus would have more demonstration value for other cities.

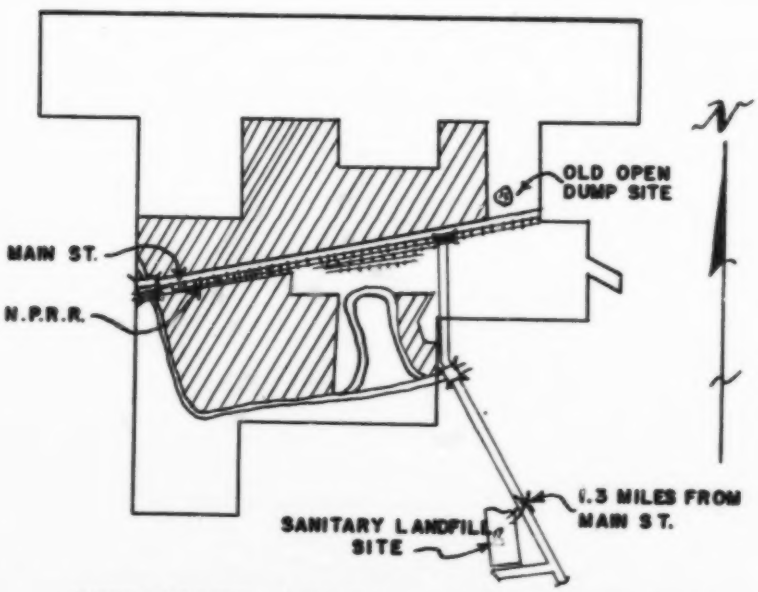

Fig. 2. Sketch of Relative Positions of Old Dump Site and Landfill Site

The topographical map of this site (see page 4) shows a 2½-percent slope at the southern end, increasing gradually to 6 percent at the north. The smooth slope of the tract was broken by a shallow ravine in the central-east portion

and a deep coulee on the northeastern end. Excellent drainage existed. Soil analysis showed a sand content of 64.2 percent (indicating ease of handling in

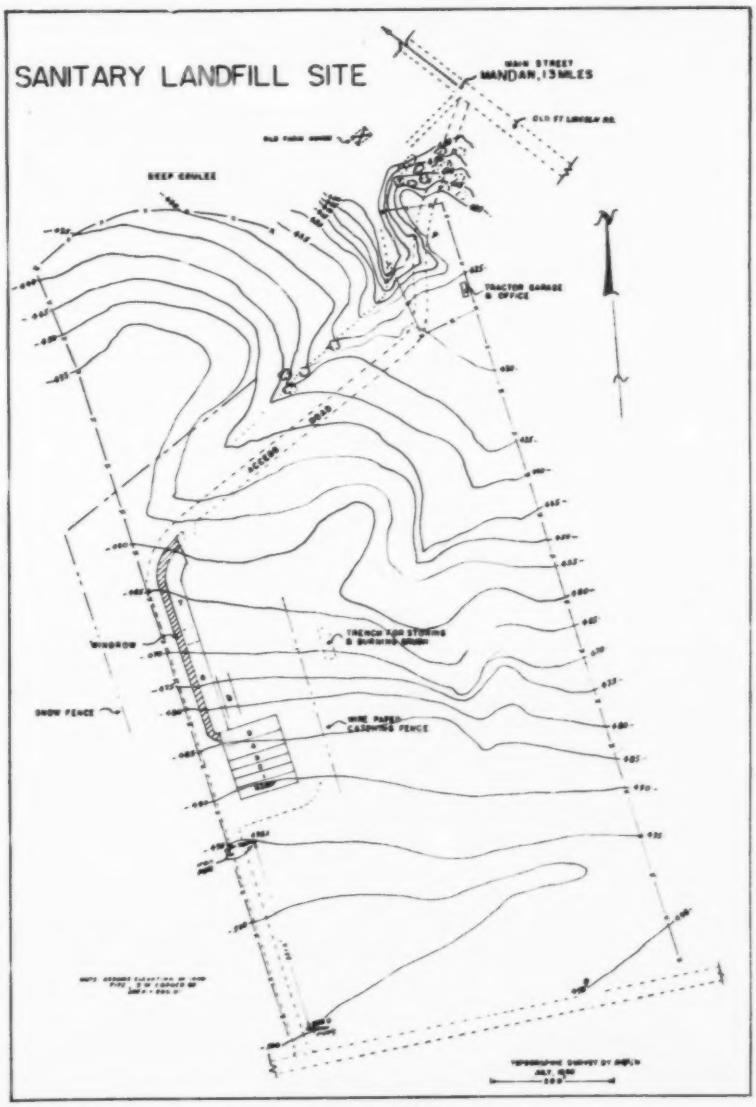

Fig. 3. Topographical Map of First Site

winter), a silt content of 13.5 percent, and a clay content of 22.3 percent, promising a minimum spring-mud problem.

A major disadvantage was the site's "northern exposure." During the 1949–50 winter, recorded wind velocities included 56 mph in November, 40 mph in December, 45 mph in January, and 36 mph in February. In August 1944, a southerly wind of 72 mph had been recorded. The high winds presented a serious problem with respect to handling waste paper.

Before operations were begun on the landfill site out of town, the rat population in the dump had to be eliminated; otherwise, their migration to new food sources could have had tragic consequences to the City. Therefore, under supervision of Mr. Mark Worchester, of the U. S. Fish and Wildlife Service, poisoning operations were carried out by employees of the City Street Department, with literally thousands of rats killed.

Plan of Operation

The first trench (No. 1 on the topographical map) was excavated in June 1949. An over-all plan was designed which permitted daily changes of dumping practices, whereby refuse could be dumped with, instead of into, the wind. This is why the fill was constructed in the form of a wide "U," with trenches numbered 1 through 5 (see figure 3) comprising the southern leg.

The topographical map was prepared to facilitate accurate planning with respect to grades, size of fill site, and other pertinent factors. It was decided to follow the natural north-south rise of 6 to 8 percent and the east-west slope of 2 to 4 percent. A 6-foot-high, dirt ramp on the west side provided a starting line, established the final grade, and provided an excellent windbreak which greatly reduced the amount of blowing paper when a truck backed into the trench to dump. Excess excavated dirt from high areas, then, could be used for cover when the fill reached the east side of the field, where the natural slope increased to 10 percent. The result would be a uniformly-sloping field with excellent drainage, which could be used again for farming.

Width and Depth of Trenches

Originally, the trenches were made no wider than 1½ times the width of the tractor, but they were widened later to approximately 17 feet (or about 2½ times the tractor width). This permitted more maneuverability when backing the municipal collection truck into the trench to protect the refuse from high winds. Trenches that are wider than this tend to reduce efficiency, because they expose too much of the face and require more cover material each evening.

Under ideal conditions, recommendations for trench depth in a sanitary landfill call for an amount of excavated dirt equal to that required for cover material —normally about 3 feet for a 1-level fill. The reasons for an average trench depth of six feet at Mandan were: (1) extra protection from the wind for vehicles dumping trash in the trench; and (2) additional dirt for the 2-level fill. The trench also reduced indiscriminate dumping (since unsupervised citizens tended, by preference, to throw their refuse into an excavation rather than on the surface).

2-Level Fill

The 2-level fill was decided on because it was desired to raise the western extremity about six feet which, with the depth of the trench, meant a total depth of 12 feet. Handling this amount of refuse in a single level presents numerous problems in small operations: It is difficult for the tractor to maintain satisfactory compaction unless the material is deposited in thin layers; building up layers to the required height produces an incline of considerable length and increases the surface area of exposed material; and fire control is handicapped, since the smothering of fires by compaction is difficult with a 12-foot-high face.

Fig. 4. Small Truck Unloading from Ramp on Second Level

The fill was constructed in two stages. First, the refuse was placed in the trench and compacted in layers to a depth of five or six feet. Then it was covered with 9 to 12 inches of dirt. When enough area on the first level was built up to permit free operation of the tractor and dumping vehicles, the second level was started. This made it possible to use the lower level when strong winds were blowing, and the upper level during periods of calm. As the material in the upper level was compacted and made ready for cover, a second trench was excavated. This method was followed during the summer and fall of 1949.

Depth of Cover

For experimental purposes, the cover applied to the compacted fill varied from one to a little over two feet. One foot of the type of soil found at Mandan

Fig. 5. Truck Dumping in Trench

seemed sufficient for public-health purposes, but varying amounts of cover actually applied, and some uneven settling, indicated a need for the two feet commonly recommended. Experience indicates that, with two feet of cover under average conditions, there will be at least one foot at all points.

Area Requirements

Approximately 5,518 cubic yards of space were required during the first year of operation, which is equivalent to the rate of 4.7 acre-feet for 10,000 population, as against the generally accepted rate of 6 acre-feet per 10,000 population. The reasons for the lower figure at Mandan were, probably, that the quantity of domestic ashes was comparatively small because of the extensive use of natural gas, and that Mandan, situated in an agricultural area, lacked the solid industrial wastes produced in other communities.

It was found necessary to guard against mixing too much dirt with the refuse, a practice which increases the amount of excavation required for cover material and deepens the trench beyond the desired depth. During muddy periods on some projects, the difficulty of maneuvering trucks may make it necessary to dump at some distance from the trench and doze it into place, in which case a mixture of dirt and rubbish is unavoidable.

Regulations at Site

The absence of regulations establishing daily dumping hours during the first year impaired the operation from both the public-health and public-nuisance

viewpoints. Each evening, all refuse was covered, the fill was neat and orderly in appearance; and no fires ever occurred in completed cells. Fires did start, however, in materials dumped haphazardly during the evening or weekend. It is apparent, therefore, that control of all dumping, and rigid enforcement of dumping hours, are necessary.

Some difficulty was encountered at first in encouraging haulers from the business district to dump at specified points, but this was gradually overcome as the public-relations aspects of the program progressed. Community support of such a project is essential. It was found that the public will cooperate when it is adequately informed of "what" and "why." Two public-relations media were used in Mandan: (1) Articles in the local newspapers; and (2) patient explanations to visitors at the site by the operator-foreman.

Wind-Blown Paper

A serious public-nuisance problem was created by wind-blown paper. This was foreseen during the planning stages, and accounted for the erection of the windrow, the depth of trenches, the 2-level design, and the U-shape of the fill. In October 1949, a 4-foot, chicken-wire fence was erected, but by November, it bulged prominently in a number of places and took on the semblance of a sinusoidal curve. This was caused, largely, by the force of the wind against paper caught by the fence. The erection of a strong, wire fence, 10 to 12 feet high, around the entire area, with periodic collection of paper caught at the bottom of the fence, might have alleviated the problem. Paper collected from the residential areas was well-mixed with garbage, had a high moisture content, and was not seriously affected by wind, but refuse from the business district was mostly paper and was blown about considerably.

Fire Hazards

Fire is not a problem when refuse is properly compacted and covered, but can occur in material deposited during the day or when the operator is off duty. In winter, especially, hot ashes may smoulder unnoticed until they burst into flame. Refuse which is compacted in the truck sufficiently to prevent fire may blaze suddenly when dumped and exposed to air. During the winter operations, trucks carrying smouldering material were unloaded at the far end of the trench in use, or in another trench. Fires which occur during the day can be extinguished by covering them quickly with refuse and compacting.

Settlement

Table I lists data on percentage and time of settlement, which were compiled by running a line of levels on the original site, at the time final cover was placed on the second level, and at the designated elapsed time shown in the table. The data shows settlement varied from zero to 18 percent. Since the percentage-of-settlement figures, by themselves, will not give an accurate picture, however, the following background information must be presented in detail.

TABLE I.—*Settlement data*

Trench Number	Date	Elevation at center line	Average original depth	Total settlement	Elapsed time (months)
			Feet	*Percent*	
Ramp (dirt)	June 1949	494.1	0–4		
	January 1950	494.2		0	7
	May 1950	494.2		0	11
	June 1951	494.2		0	24
1	July 1949	494.2	11		
	January 1950	494.2		0	6
	May 1950	494.2		0	10
	June 1951	494.3		0	23
2	July 1949	493.8	12		
	January 1950	493.6		0	6
	May 1950	493.7		0	10
	June 1951	493.7		0	23
3	August 1949	493.6	12		
	January 1950	492.9		5.8	5
	May 1950	492.4		10.0	9
	June 1951	492.4		10.0	22
4	September 1949	493.1	13		
	January 1950	492.5		4.6	4
	May 1950	492.3		6.2	8
	June 1951	492.3		6.2	21
5	November 1949	492.5	13.5		
	January 1950	491.6		6.7	3
	May 1950	491.6		6.7	7
6 Sta. 1	November 1949	485.6	14		
	May 1950	485.4		1.4	6
	June 1951	485.4		1.4	19
Sta. 2	November 1949	485.3	13		
	July 1950	484.9		3.0	6
	June 1951	484.8		3.8	19
Sta. 3	November 1949	484.6	12		
	May 1950	484.3		2.5	6
	June 1951	484.3		2.5	19
Sta. 4	December 1949	483.2	12		
	May 1950	482.8		3.3	5
	June 1951	482.8		3.3	18
Sta. 5	December 1949	481.5	10		
	May 1950	481.2		3.0	5
	June 1951	481.1		4.0	18
Sta. 6	January 1950	478.8	9		
	May 1950	477.9		10	4
	June 1951	477.8		11	17
Sta. 7	January 1950	477.9	8		
	May 1950	476.7		15	4
	June 1951	476.5		18	17
Sta. 8	February 1950	475.6	7		
	May 1950	474.7		13	3
	June 1951	474.4		17	16

The facts that too much dirt was being mixed with the refuse at first, and that a 4-week period during which trucks were driven over the area transpired before initial levels were taken, undoubtedly account for the dirt ramp and trenches 1 and 2 showing no apparent settlement over a 2-year period. The stations, or areas, completed during January 1950, were started and finished in freezing weather. Also, the trench completed in January sloped gradually to original ground level at the midway point (Nos. 6 and 7 on the topographic map) of the 300 foot trench, causing the change in over-all depth shown in Table I.

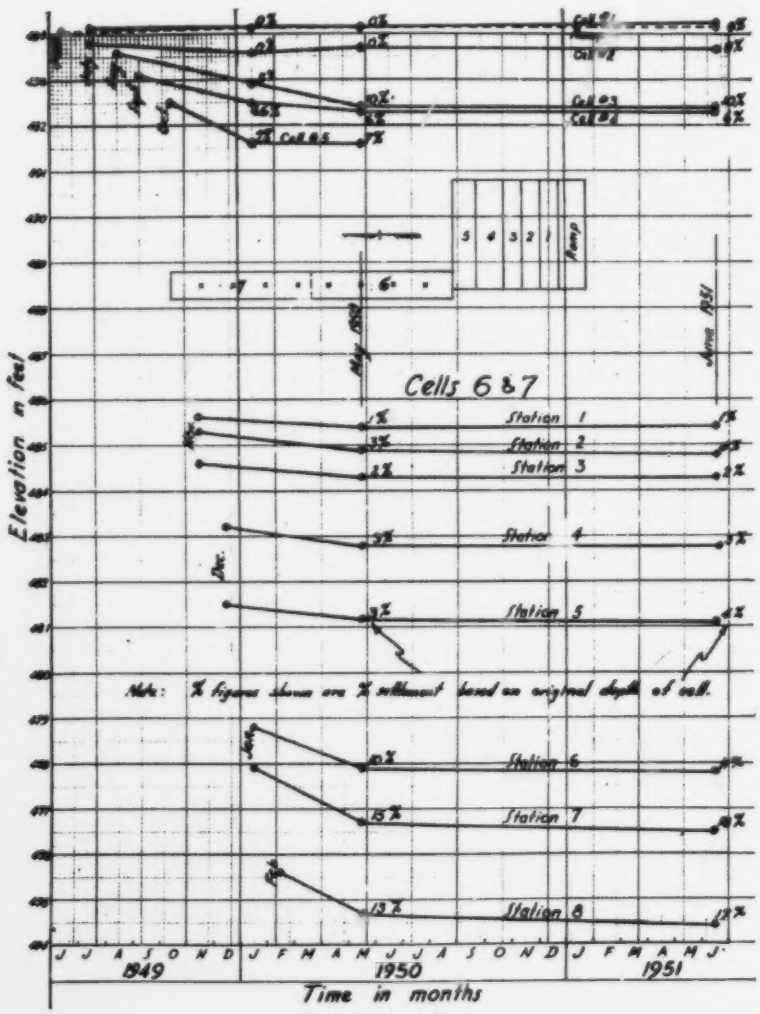

Fig. 6. Settlement Chart

The data show that there is a marked increase in the settlement of frozen refuse which is placed, compacted, and covered during sub-zero weather. This may be due to (1) reduced compaction of frozen refuse, and (2) the probability that the operator will do a less-thorough job at 20° below zero than at 60° above.

Insects and Rodents

No breeding of flies or rats was observed during summer operations at the fill. Rats emerging from trucks were quickly buried under the compacted refuse. The tractor was sprayed with DDT to protect the operator from the swarms of flies which accompanied each truck and which were drawn to bits of garbage adhering to the tractor. Compaction and covering each day seemed to eliminate the fly-breeding problem, although on larger projects it may be advisable to schedule use of insecticides both on the truck bodies and at the site.

Winter Preparations

By November 1949, a trench six feet deep, 300 feet long, and 22 feet wide had been dug and placed in reserve for winter operations. This was expected to be sufficient since, with its two levels, it provided 2,200 cubic yards, but a second reserve trench was excavated for insurance, extending 100 feet long, 25 feet wide, and six feet deep. Refuse delivered to the fill during February totalled 1,656 yards, an average of 69 yards per working day. Studies have shown that about 65 to 75 percent reduction can be expected through compaction. There were no other data on which to base an estimate at the time preparations were made, however, and as things worked out, the decision to dig the second trench was simply a "good guess." It was actually placed in use early in March 1950.

Fig. 7. Tractor Compacting Refuse

Fig. 8. Obtaining Cover from Stockpile

To provide cover material for the period when it was thought it would be impossible to excavate, some 700 cubic yards of dirt from the trenches dug in the fall were stockpiled in windrows, as close to the working area as possible. About 100 feet from a trench seems to be a practical distance for a stockpile. If more distant stockpiles should be necessary, the material should be moved by truck.

To keep the stockpiled earth loose, it was piled without running the tractor over it. The windrows were built with their axes parallel to the prevailing northwest winds, so that the wind would keep snow off; and their sides were sloped steeply, to shed rain. The moisture content of the sandy loam at the site was 9.2 percent at excavation time, and 4.9 percent when sampled from the stockpile in January. There was not enough lumping to be a serious problem when moving the stockpiled earth for cover.

Weather Data

January 1950 was the coldest January ever recorded in that area, with an average temperature of minus 10.2° F. (See Appendix I for official Weather Bureau report.) Over 72 inches of snow fell during the winter, up to May 1—more than ever before recorded; and snow fell during May also. A good measure of the severity of the winter was the fact that the Missouri River ice breakup occurred April 15, later than ever before. Nevertheless, because snow fences had been placed, as recommended by the State Highway Department, snow-drifting caused no difficulties at the landfill site, and snow did not accumulate in large quantities in the excavated trenches. The topographical map (page 4) shows the fences, located 100 feet from the windrow.

Fig. 9. Finishing Portion of Fill

Winter Equipment Problems

Equipment problems were surprisingly few. The City built a garage at the site, in which an oil stove, burning continuously, held the temperature at 20° to 30° F., and made possible the daily starting of the diesel-driven tractor.

It proved necessary to equip the tractor with grousers when working on ice or hard-packed snow. Year-long use of grousers, of course, would have limited the tractor's versatility during non-winter months, since the grousers might damage paved streets. A well-constructed, heated tractor-cab will enable the operator to work efficiently during winter operations.

Frost-Penetration Studies

Frost-penetration studies in the Mandan area showed that the depth of penetration seemed to vary with the state of the soil and late fall moisture conditions prior to the first permanent freeze. Soil on prairie or farm land which was relatively undisturbed, and insulated with early snow, had frost penetrations of a few inches to 1½ feet. Earth which had been compacted or driven over had frost penetrations of from four to five feet. Leaves from streets which were sodden from rains just prior to collection offered relatively little insulation against frost.

Experiments at the Mandan site, and information received on other winter excavations, indicate that either of the following steps may be taken to facilitate winter landfill operations in northern regions:

1. Plow or scarify the area to be excavated before the frost arrives; place insulating material (leaves, hay, etc.) to a depth of about three feet; replace insulating material over the working area as the trench is excavated.

2. Excavate the required number of trenches in advance and stockpile the cover material; work the stockpile if wet, to insure drying in the fall; protect the stockpile with leaves, placed in the form of cells, with each cell being opened as cover material is needed.

It should be noted that in Bismarck, North Dakota, a sanitary landfill was started in the spring of 1951. Cover was excavated from an undisturbed, well-drained prairie area, during the entire winter's operation of 1951-52. Soil analysis of the excavated material showed 55 percent sand, 24 percent silt, and 21 percent clay.

Since the above methods have not been tried under all conditions, it is not certain that they will completely solve the problem of operating a sanitary landfill in severe winter weather.

To find a sound basis for judging the suitability of certain types of soil for winter operations, the following suggestions were made by Dr. H. W. R. Larson, Ph.D., Acting Chief, Land Resources, Bureau of Reclamation Soils Laboratory, at Bismarck, North Dakota:

1. For all soils: Mechanical analysis.

2. For heavy soils: A. Determination of the sulphate ion as a test for gypsum content, and determination of the lime content. This would indicate the porosity and, thus, how easily the soil could be handled.

B. Determination of exchangeable sodium would indicate whether or not the soil would work in lumps.

These tests are suggested merely as an avenue of investigation. It is hoped that standards will be developed which will enable a field man to submit a soil sample from a proposed landfill to a soils laboratory, and obtain clearer foresight on the problems he may encounter.

The New Site

Spring floods, and other factors, forced the end of work at the trench-landfill site on March 22, 1950. The road to the landfill site was completely flooded, and a new base had to be found quickly. The City Council, impressed by the sanitary operation of the landfill during the preceding winter, moved the site to the vicinity of the old dump. It was planned to fill this area to grade, for eventual use as a baseball park.

Previously, in September 1949, an investigation had been undertaken into the old dump, during which a trench was bulldozed, extending 25 feet back from the face, and from 2 to 6 feet deep. Analysis of the uncovered material was made at the Bureau of Reclamation Soils Laboratory, and results (moisture content 19.15 percent; 13.5 percent loss on ignition; 13.05 percent organic content) indicated that it would be satisfactory cover material.

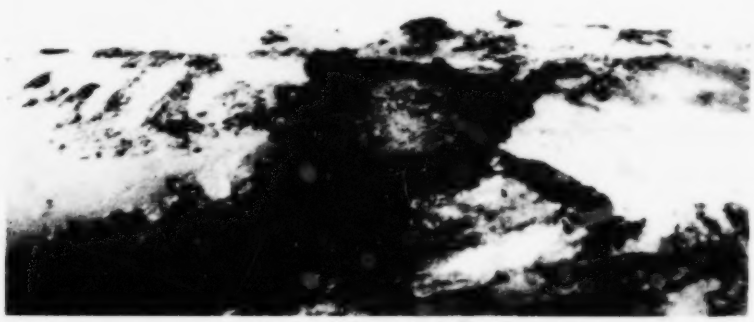

Fig. 10 Excavation into Face of Old Dump

A further check in February 1950, going deeper into the fill, demonstrated that the material could be excavated under winter conditions. However, a preponderance of tin cans, logs, etc., was uncovered at the bottom of the fill. It was concluded, therefore, that while all the residue from an old dump cannot be used for cover material on a sanitary landfill, selected material near the surface can be used. This would be important to a community desiring to convert from an open dump to a sanitary landfill when cover material is scarce.

Fig. 11. Closeup of Figure 10

In the new area to be filled, water from the spring run-off was three feet deep, making cover material impossible to obtain by trenching with available equipment. Part of the cover used came from the upper layers of the old dump, and part from a nearby hill. The various phases of the operation are shown in figures 12 through 14. The height of the fill was 12 to 15 feet, making it necessary to deposit refuse in two layers, for reasons similar to those previously given.

Fig. 12. Slough Area Adjacent to Old Dump

Fig. 13. Filling Slough Area

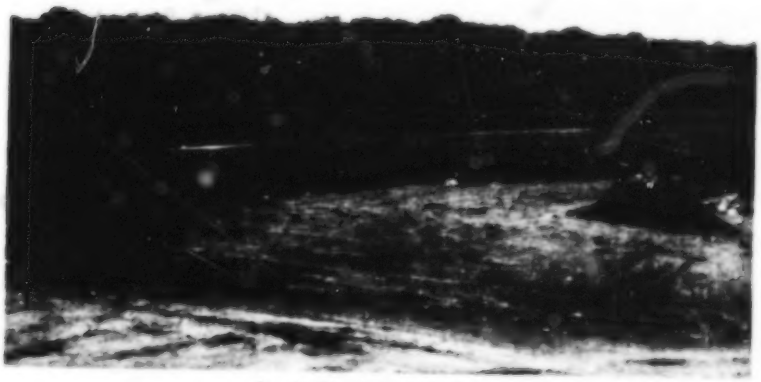

Fig. 14. Slough Area after Filling

Small Community Operation

With proper planning and efficient operation, a 5,000-population community should be able to operate a sanitary landfill. On a project of this size, the tractor is required only two or three hours daily, and is available the rest of the day for other municipal operations—gravel-loading, snow-removal, street-excavation, etc. This arrangement would necessitate regulated dumping hours at the landfill site, to prevent refuse being scattered about during evenings and weekends, and making the area resemble an open dump.

Smaller communities might modify the landfill method by a form of sanitary trenching. It would, usually, be necessary to clean up the site before excavating a trench. Since the accumulation on small dumps can generally be moved only with heavy equipment, the trench may have to be dug by county or rented contractor equipment. The refuse should be compacted and covered at least twice a week in warm weather, and as often as practicable in the winter.

If heavy equipment cannot be obtained, an ordinary farm tractor equipped with a small front-end-loading bucket or bulldozer blade can be used, provided such large items as tree limbs, car fenders, barrels, etc., are removed first. This can be accomplished by placing signs designating a separate dumping trench or area for such large objects. It would not be possible to control fires completely, but a deliberate program of burning household refuse is not recommended in this modified version of the sanitary landfill.

A simple outline of a program for a small community is:

1. Tell the public *how*, *why*, and *what* you are going to do.
2. Clean up the old dump and build an all-weather road to the site, using rented heavy equipment, if necessary.
3. Dig a trench, store dirt at ends or on sides, and designate a specific area for large objects.
4. Work over refuse in the trench; cover the top and face with at least two feet of dirt on the schedule mentioned above.
5. Each spring, incorporate the large objects into the fill, burn the accumulated brush, and dig a new trench.

Sanitary trenching, while less desirable than a sanitary landfill, is a vast improvement over the usual small open dump.

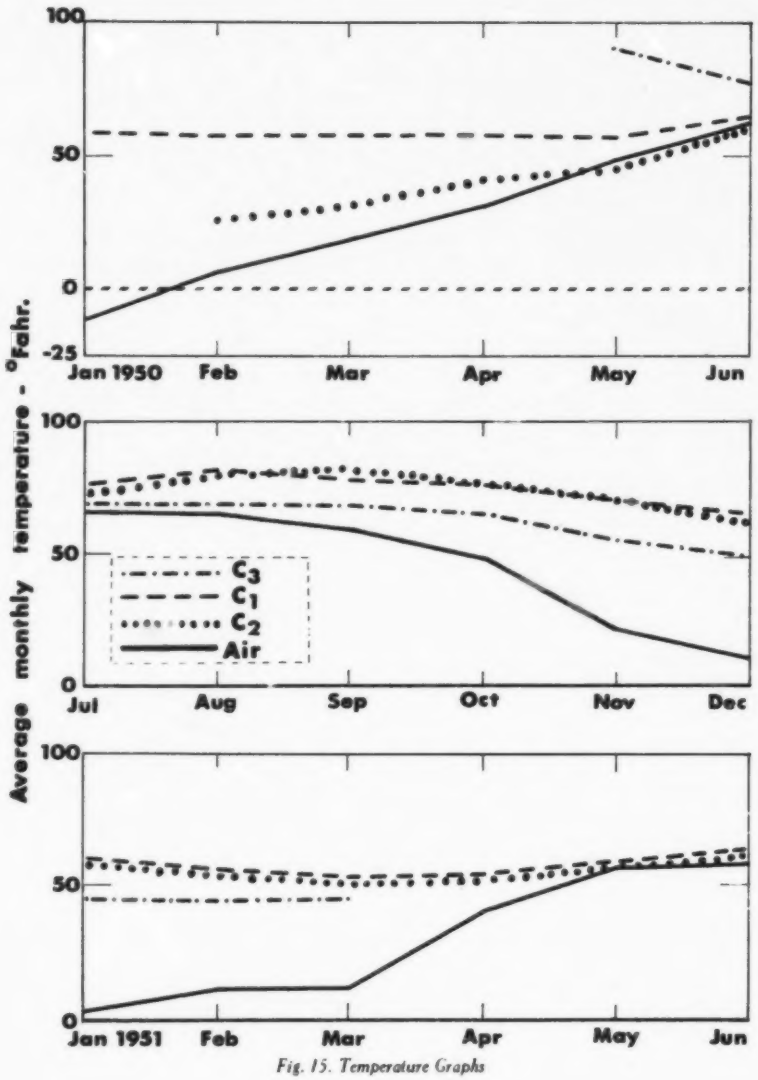

Fig. 15. Temperature Graphs

Temperature Studies

Temperature data are important in the study of sanitary landfills. High temperatures in a closed cell result from anaerobic bacterial activity; the degree and duration of heat are excellent measures of decomposition occurring in the cell.

Temperature graphs of three cells—C_1, C_2, and C_3—are shown in figure 15. Cell C_1 was completed in November 1949, but temperature-recording equipment was not obtained until January 1950. However, the C_1 graph shows that a stable temperature was held throughout the winter, evidently independent of atmospheric conditions. The conclusions reached from study of the temperature graphs are as follows:

Cell C_1—Refuse placed in summer or fall holds a temperature throughout the winter, regardless of atmospheric conditions.

Cell C_2—Refuse placed, compacted, and covered in freezing weather generates little or no heat from decomposition, until atmospheric temperature rises high enough to permit bacterial activity.

Cell C_3 was started and completed in warm weather, during which the temperature rose to a peak of 93° F. and dropped to 83° F. within a 2-week period. So short a record will not tell a complete story, but the rise to 93° (rather than 130° or 140°) would seem to indicate a high content of rubbish in the refuse.

If the Mandan site can be considered typical, the reason for the slow decomposition in a sanitary landfill is probably the relatively high content of rubbish, which does not provide optimum environment for bacteria. It should be emphasized, also, that the prevailing climate of North Dakota is exceedingly dry. In some areas, therefore, it may be necessary to provide a catalyst to promote complete bacterial reaction within a reasonable time.

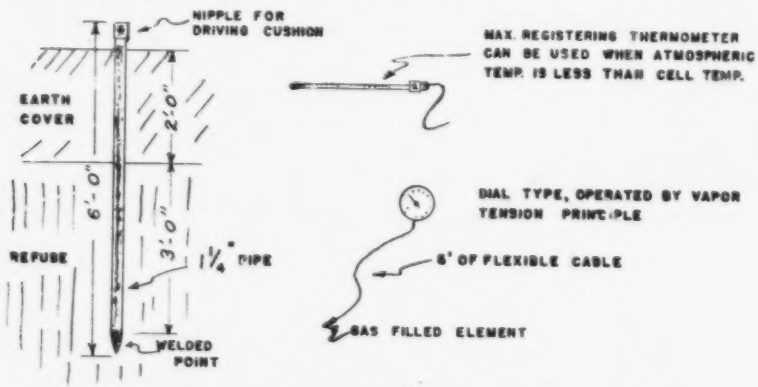

Fig. 16. Temperature Apparatus

Experiments were conducted with temperature-registering equipment which (see Figure 16) was inexpensive and easily obtained. The maximum-registering

thermometer, familiar to all milk sanitarians, and the prepared 6-foot length of pipe, were not expensive. This thermometer, generally, cannot be used when atmospheric temperature is greater than cell temperature; for a complete year-long graph, a dial-type thermometer (Figure 16) is desirable.

TABLE II.—*Physical-Analysis Results*

	Residential					Business (Restaurants, Etc.) June 7, 1950	
	June 7, 1950		August 22, 1950		Percent of Total		
	Pounds	*Percent*	*Pounds*	*Percent*		*Pounds*	*Percent*
Garbage	1,207	47	1,134	48	47	880	64
Paper	538	20	439	18	20	324	23
Rubber, wood clippings, etc.	325	12	430	18	15	93	7
Metal	186	7	189	8	7	49	4
Ashes	184	7	Negligible		4		
Glass	148	6	153	6	6	35	2
Rags	28	1	28	2	1		
Total	2,616	100	2,373	100	100	1,381	100

Physical Analysis

Physical analyses were performed to determine the relative quantities of paper, rags, etc., in the refuse at Mandan. For this, a representative sample must be sorted by hand, preferably at seasonal periods. Table II shows the results of the three analyses it was possible to make. Since physical analysis of refuse collected by the combined method is difficult, at best, probably the most accurate data can be obtained from communities having separate collections.

Statistics show that about half of the refuse from the Mandan business district is hauled by commercial haulers, with the other half delivered to the disposal area by the business people themselves (called private haulers in this report). Almost all the refuse from Mandan restaurants is hauled by commercial haulers; thus, the 64-percent garbage shown on Table II is probably high for the business district as a whole.

Chemical Analysis

The Public Health Service laboratories at the Environmental Health Center, Cincinnati, Ohio, performed chemical analyses of raw-refuse samples from Mandan. Similar analyses were made of refuse buried for periods of one and two years. It is hoped to correlate data on chemical characteristics of refuse over a decomposition period of several years.

After considerable experimentation, the following method was used to obtain a representative sample of the refuse:

1. The accumulated refuse for one morning was thoroughly mixed and compacted.

2. Five holes were dug with a spade auger with sharpened blades (other types were found unsatisfactory) in the pattern of the five spots on a die.

3. This material was mixed and quartered until the desired sample size was obtained.

Table III shows the results of these analyses.

The average BOD for the 10 monthly "fresh" samples of refuse was 77,050 ppm. That of the 1-year sample was 30,000 ppm, and of the 2-year sample, 23,500 ppm, thus showing that considerable decomposition had taken place. The decrease in the amount of ammonia as nitrogen also substantiated this conclusion. However, a considerable amount of decomposition remained to be accomplished at the end of two years. The extremely high BOD values are very significant factors to be taken into account when possible water pollution is considered in the location of a landfill. It is intended to have additional analysis made of the buried refuse in the future for further evaluation of decom position characteristics in the Mandan fill.

Quantitative Data

For reasonably accurate weight and volume data, figures for a full year are desirable, including those on all refuse deposited in the fill—from municipal, commercial, and private haulers. Weighing was started in Mandan in February 1950, and continued through September 1950. These data are shown in Table V. Two interesting facts brought out are (1) the average of 2.9 pounds per capita per day, and (2) the almost equal division between business and residential refuse.

The cubic-yardage figures should not be used for comparison with those from other communities, since experience in Mandan indicates that such is considerably influenced by local conditions. Depending on the mechanical condition of the 12-yard packer truck, loads varied from 60 percent to 80 percent of capacity. Therefore, an assumption that 50 loads totaled 600 yards could be as much as 40 percent in error. Also, yardage from a non-packer truck cannot be considered the same as packed cubic yards; nor can the Mandan yardage be compared with that of a community using packer trucks only.

Cubic-yardage data may be excellent for comparative use within the community, where all the quirks of the system are known to the superintendent or engineer in charge, but for the exchange of area or inter-city data, weight statistics appear to be much more reliable.

TABLE III.—*Chemical-Analysis Results*

Analysis	Refuse ready for burial											Buried sample	
Date sample collected	February 6, 1950	March 6, 1950	April 13, 1950	May 10, 1950	June 6, 1950	July 15, 1950	August 21, 1950	September 10, 1950	November 17, 1950	December 10, 1950	Average	1 Year July 15, 1950	2 Years July 14, 1951
Total Solids (percent)	53.32	51.41	44.08	51.44	60.35	43.35	46.26	31.53	37.81	29.36	44.89	37.37	66.1
Volatile Solids (percent)	31.69	20.18	17.26	15.28	39.53	16.98	27.44	13.71	20.07	23.12	22.52	11 95	21.5
Fixed Solids (percent)	21.63	31.23	26.82	36.16	20.82	26.37	18.82	17.82	17.74	6.24	22.36	25.42	44.6
pH	5.9	7.77	8.8	6.4	5.0	6.3	6.3	7.4	6.0	5.5	6.5	6.0	6.6
Acidity to P.P. as $CaCO_3$ (ppm)	756	158	128	540	3,540	923	3,000	2,064	5,375	5,910	2,239	1,853	146
Alkalinity to M.O. as $CaCO_3$ (ppm)	14,650	8,352	12,700	7,740	10,625	2,667	21,000	13,300	23,100	17,190	13,132	727	2,300
Ammonia as N (ppm)	252	144	46	120	340	862	408	500	73	154	289	320	163
Total nitrogen as N (ppm)	6,945	3,749	2,646	1,980	10,115	5,460	6,138	3,970	5,623	6,950	5,357	3,118	2,000
Oxygen consumed (ppm)	394,023	269,000	170,000	168,800	501,500	238,000	356,000	187,000	227,000	258,400	270,972	208,000	230,000
5-day B.O.D. (ppm)	95,900	63,000	39,000	14,200	178,500	41,000	106,000	39,000	70,900	123,000	77,050	30,000	23,500

Costs

A study of operational costs for the 1-year period, as presented in Table IV, permits close estimates to be made of the expense of a sanitary landfill for a community approximately the same size as Mandan. The average monthly cost was:

Equipment operator (8-hour day, 6-day week)	$235.69
Operating costs (fuel, grease, repairs)	27.35
General expenses (fencing, land, etc.)	22.00
Tractor amortization ($8000 at 4% amortized over 5 years)	144.00
Total	$429.04

The average amount of refuse deposited monthly (Table V) for February through September was 323.03 tons. Applying this to the 1-year period of operation brings the disposal cost to $1.33 per ton. Previously, Mandan had employed a dump attendant at $150.00 per month. The increased monthly cost for the landfill, therefore, was $279.04, or $0.86 per ton.

There were 255 working days in the 10-month period (tractor work hours were not obtainable for June and July), during which the tractor and operator worked 536 hours, or an average of 2.1 hours per working day. If they had been used on other municipal projects for only one-half of the possible working time, the costs might be estimated as follows:

Wages (4-hour day, 6-day week—$235 2)	$117.50
Operating costs	30.00
General expenses	25.00
Amortization ($144 2)	72.00
Total	$244.50

This would reduce the cost per ton (based on 323.03 tons per month) to $0.76.

Repair costs over a 5-year period will, as a rule, be larger than those at Mandan, but may be offset by salvaging used equipment, by careful operation and maintenance of equipment, and by judicious use of municipal repair facilities and labor. Because of the variability of these factors, no estimate of higher repair costs for equipment as it ages is included.

Few communities include amortization of equipment in their cost tables. If we eliminate the amortization figure, the cost per ton is reduced to $0.53, which is near the cost-per-ton commonly reported for a sanitary landfill. It is readily apparent, however, that actual costs depend on what is charged to the operation by the community, as well as the ability to operate a planned and efficient program.

TABLE IV.—*Monthly Cost Tabulation*

	August 1949	September 1949	October 1949	November 1949	December 1949	January 1950	February 1950	March 1950	April 1950	May 1950	June 1950	July 1950	Average per Month
Liability insurance (tractor)	$1.70	$1.70	$1.70	$1.70	$1.70	$1.70	$1.70	$1.70	$1.70	$1.70	$1.70	$1.70	
Maintenance and repairs	None	[1]	None	None	None	None	None	13.80	None	None	None	12.50	
Old-age & survivors insurance @ 1 percent	2.48	2.39	2.41	2.22	2.39	2.31	2.21	2.48	2.30	2.39	2.39	2.30	
Fuel oil @ 16.8 cents per gallon	21.84	17.64	18.48	16.02	10.08 [2]5.04	10.08 [2]20.16	10.43 [2]22.44	9.74 [2]19.15	12.43	14.28	9.24	16.96	
Crank-case oil @ $0.75 1/2 gallon	3.96	.94	1.51	1.51	1.51	1.51	.76	.38	.76	.38	2.26	1.51	
Grease @ 14 cents per gallon	.35		.14	.28	.14	.07	.04	.14	.14	.14		.42	
Subtotal	30.33	22.67	24.24	21.73	20.86	35.83	37.58	47.79	17.33	[3]8.89	15.59	35.39	27.35
Labor (operator-foreman) @ $1.15 per hour, 8-hour day; 6-day week	248.40	239.20	240.73	222.00	239.20	231.15	220.80	248.40	230.00	239.20	239.20	230.00	235.69
Total	278.73	261.87	267.97	243.73	260.06	266.98	258.38	296.19	247.33	258.09	254.79	265.39	263.04
Estimated expenditures (land, garage, incidentals, etc.[3])	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00
Amortization of tractor over 5 years ($8,000 @ 4 percent)	144.00	144.00	144.00	144.00	144.00	144.00	144.00	144.00	144.00	144.00	144.00	144.00	144.00
Grand Total	444.73	427.87	430.97	409.73	426.06	432.98	424.38	462.19	413.33	424.09	420.79	431.39	429.04
Tractor operating hours	80	53	57	53	50	42	44	51	49	57	[4]	[4]	53.6

[1] Broken clutch plate, defective material (repaired under warranty).
[2] For stove in garage.
[3] Land (cost $600); Garage (cost $600). Amortized in 10 years @ 4 percent or $12 per month. Incidentals $10 per month.
[4] Figures not available.

TABLE V. *Refuse-quantity data*

Month	Number of collection days	Number of Loads		Weight (tons)		Cubic yards		Percent (by weight)		Total cubic yards	Total tons	Pounds per capita per day
		Municipal	Commercial and private	Municipal	Commercial and private	Municipal	Commercial and private	Municipal	Commercial and private			
February	24	94	278	120.90	103.04	752	904	54.0	46.0	1,656	223.94	2.2
March	27	117	321	144.13	130.48	1,038	663	52.5	47.5	1,701	274.61	2.4
April	25	132	332	182.00	166.52	1,173	630	52.2	47.8	1,803	348.52	3.2
May	27	142	474	197.35	265.79	1,148	876	42.5	57.5	2,024	463.14	4.1
June	26	145	476	163.82	172.20	1,323	617	48.7	51.3	1,940	336.20	3.1
July	25	150	400	152.60	156.03	1,368	443	49.4	59.6	1,811	308.63	2.7
August	26	141	409	171.34	142.87			54.5	45.5		314.22	2.8
September	24	99	362	129.58	185.85			41.0	59.0		315.43	2.8
Average per month	25.5	127.5	381.5	157.72	165.35	1134	689	48.7	51.3	1,823	323.07	2.9

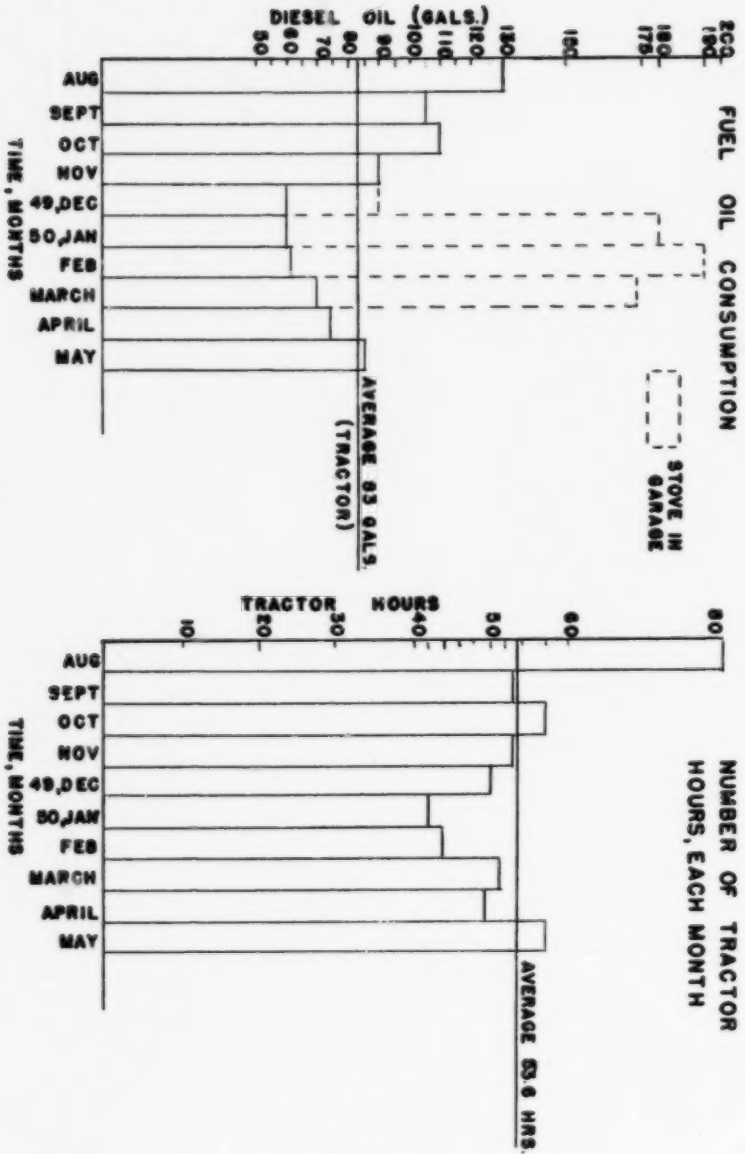

Fig. 17. Fuel Oil and Tractor Hours

Summary

Choosing a Site

One of the primary reasons for the success of the first winter's operation was the sandy soil available at the first site. By excavating sufficient trenches in advance and stockpiling cover material, it was possible to operate the sanitary landfill in temperatures as low as −44° F. Enough experimental winter-operating data were gathered to enable recommendation of the following soil-preparation procedures for possible operation in other areas:

1. Scarify area prior to frost, and insulate with material such as leaves;
2. Excavate trenches in advance; stockpile cover, insulating with material such as leaves, if necessary.
3. Possibly, excavate undisturbed area.

Operation

The two most difficult problems encountered at the first site were promiscuous dumping and blowing paper. The former can be remedied by dumping regulations and public education; the latter by erection of fences as "paper catchers," proper planning of fill, and, most important of all, proper selection of site. There was no paper-blowing problem at the second site because it was protected by high hills.

Special tractor needs in extreme winter operation are ice grousers, a heated cab, and a garage. These accessories will redeem themselves in added efficiency of operation.

Experimental Data

At Mandan, complete refuse decomposition was not experienced after a 2-year period of burial. Although considerable decomposition had taken place, a great deal more remained to be accomplished.

Settlement varied from zero to 18 percent, depending on prevailing climatic and operating conditions during burial.

Conclusions

Since the ultimate use or re-use of any area reclaimed by the sanitary-landfill method of refuse disposal is governed primarily by the decomposition of the refuse, the possibility of seeding or providing a catylyst (such as control of moisture with water) when building the refuse cells warrants more detailed study.

The primary objective of the Mandan experimental sanitary-landfill project was to determine the feasibility of operating a sanitary landfill in extreme winter conditions. Although the techniques found successful at Mandan may need to be varied somewhat to meet local conditions, two years of highly successful, year-round operation have answered this question in the affirmative.

APPENDIX I — *U. S. Department of Commerce, Weather Bureau — Station Meteorological Summary*

Station, Bismarck, N. Dak. (Airport); Month, January; Year, 1953; Central Standard Time

Day	Temperature °F					Precipitation (in.)		Wind				Sunshine		Sky cover		Thunderstorm or distant lightning	Visibility ¼ mi. or less caused by	Missouri river stage		
	Maximum	Minimum	Average	Departure from normal	Degree days (base 65°)	Total water equivalent	Snowfall, sleet, hail	Snow, sleet, hail, or ice on ground at 6:30 p.m.	Prevailing Direction	Average speed m.p.h.	Fastest mile: Speed m.p.h.	Fastest mile: Direction	Total hours and tenths	Percent of possible	Sunrise to sunset (tenths)	Midnight to midnight (tenths)					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	9	−3	3	−5	62	T	T	4	NNW	12.5	27	N	6.27	75	8	8			5.8		
2	−1	−11	−6	−14	71	.01	.2	4	NNW	17.9	26	N	3.09	37	10	10			5.8		
3	−11	−19	−15	−23	80	T	T	4	NNW	17.6	28	NW	5.11	60	10	10			5.7		
4	−7	−32	−20	−27	85	T	T	4	SW	4.9	15	SE	8.40	100	0	1			5.6		
5	9	−22	−7	−14	72	0	0	4	SSW	7.0	21	SW	8.41	100	0	0			5.6		
6	21	−16	3	−4	62	0	0	4	E	6.8	13	NE	6.03	69	5	3			5.6		
7	2	−21	−10	−17	75	0	0	4	SSE	10.5	24	SE	4.38	53	4	5			5.7		
8	12	−8	2	−5	63	0	0	4	NNW	6.6	13	E	5.13	59	9	8			5.9		
9	0	−11	−6	−13	71	.13	2.8	6	NNW	11.3	22	N	0.00	0	10	7			6.0		
10	−3	−18	−11	−18	76	T	T	7	NW	12.0	29	NW	8.48	100	0	1			6.0		
11	25	−14	6	0	59	0	0	7	ESE	10.5	29	NW	7.50	89	6	7			6.0		
12	−1	−15	−8	−14	73	0	0	7	NNW	10.8	24	NW	8.53	100	1	1			6.0		
13	−8	−23	−16	−22	81	.10	2.0	9	NW	13.3	27	NW	0.00	0	10	7			6.0		
14	−15	−29	−22	−28	87	.03	.5	8	ENE	8.1	16	E	3.01	34	9	7			5.8		
15	−15	−25	−20	−26	85	T	T	9	WNW	17.0	29	W	8.50	100	2	3			5.4		
16	−6	−24	−15	−21	80	T	T	9	WNW	8.4	24	NW	3.54	43	10	7			5.3		
17	−11	−31	−21	−27	86	.05	1.3	10	NNW	11.5	21	N	4.30	50	5	6			5.1		
18	−5	−44	−25	−31	90	0	0	9	ENE	4.2	13	W	9.05	100	0	1			4.9		
19	1	−23	−11	−17	76	0	0	9	SSE	6.9	15	NW	3.59	44	8	6			4.8		
20	11	−2	5	−1	60	.22	3.2	11	ESE	8.0	16	E	6.14	68	9	9			4.8		
21	25	4	15	+9	50	0	0	11	SSE	8.5	20	N	1.52	20	9	9			4.9		
22	12	−5	4	−2	61	.14	1.7	12	ENE	13.8	29	E	0.00	0	10	10			5.1		
23	5	−9	−2	−8	67	.22	3.8	15	E	18.7	42	E	0.0	0	10	10			5.2		
24	6	−20	−7	−13	72	.05	.9	16	NW	24.5	45	NW	1.29	16	10	10			5.4		
25	−20	−32	−26	−32	91	T	T	15	NW	9.8	16	NW	5.01	32	9	5			5.4		
26	−11	−38	−25	−31	90	T	T	14	ESE	6.5	17	S	7.46	83	6	4			5.3		
27	−7	−28	−18	−24	83	0	0	14	ESE	7.1	15	E	4.37	49	7	6			5.3		
28	−1	−18	−10	−16	75	.03	.5	14	NNW	16.9	34	NW	0.50	9	10	9			5.2		
29	−7	−32	−20	−26	85	0	0	14	WNW	6.4	20	W	9.31	100	0	0			5.2		
30	−10	−35	−22	−28	87	T	T	14	NNE	4.0	13	N	2.33	27	10	8			5.2		
31	6	−31	−14	−20	79	T	T	14	W	7.4	20	W	8.43	91	1	2			5.2		
Sum.	5	−638				1.09	16.9			329.4			153.37		198	183			169.2		
Avg.	0.2	−20.6							Prevailing	10.6	Fastest	Direction	Possible	%	6.4	5.9			5.5		
								Mon.			45	NW	280.13	55							

Temperature data

Average monthly	—10.2
Departure from normal	—16.5
Highest	25 on 21st
Lowest	—44 on 18th
Number of days with—	
Max. 32° or below	31
Max. 90° or above	0
Min. 32° or below	31
Min. 0° or below	30
Degree days (base 65°)—	
Total this month	2334
Departure from normal	+614
Seasonal total	5767
Departure from normal	+552

Precipitation data

Total for the month	1.00 in.
Departure from normal	+.55 in.
Greatest in 24 hours	0.27 on 23-24

Snowfall, sleet and hail

Total for the month	16.9 in.
Greatest in 24 hours	4.5 on 23-24
Greatest depth on ground	17 on 23-24

Barometric pressure

Monthly mean station	28.26 in.
Highest sea-level	30.68 in. on 7th
Lowest sea-level	29.54 in. on 24th

Weather

Number of days—	
Clear (scale 0-3)	8
Partly cloudy (scale 4-7)	6
Cloudy (scale 8-10)	17
With 0.01 inch or more precip.	10
With 0.10 inch or more precip.	5
With 0.50 inch or more precip.	0
With 1.00 inch or more precip.	0
Dates of—	
Hail	0
Sleet	0
Glaze	0

Symbols used in columns 18-19

A = Hail
BS = Blowing snow
DL = Distant lightning
D = Dust
E = Sleet
F = Fog
H = Haze
K = Smoke
L = Drizzle
N = Sand
R = Rain
S = Snow
T = Thunderstorm
ZL = Freezing drizzle
ZR = Freezing rain

This was the coldest January in the climatological history of Bismarck. More snow fell than in any previous January. Temperatures at the airport, where readings are now made, average two to three degrees lower than in the city during cold weather.) The 21st was the only day with the minimum temperature above zero. Wind and sunshine averaged near the seasonal normal. Blowing snow occurred on the 1, 2, 3, 7, 9, 10, 17, 22, 23, 24, 28. Blizzard conditions existed the afternoon of the 23rd and continued until the 25th.

Subscription Price: 50 cents per year including annual summary if published. Separate copies, monthly 5 cents each, annuals 10 cents each. Checks and money orders should be made payable to the Treasurer of the United States. Correspondence regarding subscriptions should be addressed to the Weather Bureau Office in the city for which this summary was issued.

WBO, Kansas City, Mo.—2-7-50—100

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